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Trophic ecology of the pikeperch (*Sander lucioperca*) in its introduced areas: a stable isotope approach in southwestern France

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Abstract

During the last decades, non-native predatory fish species have been largely introduced in European lakes and rivers, calling for detailed information on the trophic ecology of co-existing native and non-native predators. The present study describes the trophic ecology of the introduced pikeperch (*Sander lucioperca*) in two southwestern French rivers, using stable isotope analysis. Pikeperch could be categorized as a top-predator, and had a significantly higher trophic position (TP, mean \pm SE = 4.2 ± 0.1) compared to other predatory fish such as the native pike (*Esox lucius*, TP = 3.7 ± 0.1) and the introduced European catfish (*Silurus glanis*, TP = 3.8 ± 0.1). Most studies of resource use in freshwaters consider predatory fish as ecologically equivalent; however, this study showed that the pikeperch occupied a higher trophic niche compared to other predatory species in the Lot and Tarn rivers (Garonne River basin). This apparent specialization may thus have consequences upon interspecific relationships within the predatory guild and upon the functional organization of biological communities.

Résumé

Écologie trophique du sandre (*Sander lucioperca*) dans son aire d'introduction : approche isotopique dans le sud-ouest de la France. Durant les dernières décennies, de nombreuses espèces de poissons exotiques, comme le sandre (*Sander lucioperca*), ont été introduites dans les écosystèmes aquatiques européens à la fois pour leur valeur économique et leur intérêt halieutique. Le but de cette étude est de déterminer à l'aide des isotopes stables l'écologie trophique du sandre dans deux rivières du sud-ouest de la France. Dans les deux rivières, le sandre présente une position trophique significativement supérieure (TP, moyenne \pm erreur standard = $4,2 \pm 0,1$) à celles des autres prédateurs comme le brochet (*Esox lucius*, TP = $3,7 \pm 0,1$) ou le silure (*Silurus glanis*, TP = $3,8 \pm 0,1$). La plupart des études concernant l'utilisation des ressources en eau douce considèrent les poissons prédateurs comme écologiquement équivalents. Dans les systèmes étudiés (Lot et Tarn, bassin de la Garonne), le sandre occupe une niche trophique plus élevée que les autres poissons prédateurs. Cette spécialisation apparente pourrait ainsi avoir des conséquences sur les relations interspécifiques au sein de la guildes des prédateurs, et sur l'organisation fonctionnelle des communautés biologiques.

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Mots-clés : Espèces exotiques ; Prédateurs ; Piscivores ; Position trophique ; Lot ; Tarn ; Bassin de la Garonne

1. Introduction

The introduction of non-native predatory species can impact food webs and native populations of predators and prey [1]. The most obvious effects of introduced predators are lethal or non-lethal direct effects *via* predation on and/or competition with native predators [2, 3]. Freshwater ecosystems have little immunity to non-native fishes [4], which were introduced for many recreational and economic purposes [5]. For instance, rivers have been heavily stocked with non-native predatory fish species for recreational fisheries [6], and one of them is the pikeperch, *Sander lucioperca* (Linnaeus, 1758). The native distribution of the pikeperch extends from Germany in the Western Europe through the Baltic Sea drainage area to the Southeast part of Russia. Since the beginning of the 19th century, pikeperch has been introduced in several countries and nowadays, the species occurs from the Iberian Peninsula to the Aral Sea and from Scandinavia to Maghreb [7]. Specifically, pikeperch has been introduced in France since the beginning of the 20th century [5] and it has been recorded since 1960 in southwestern French rivers [8]. In its native areas, pikeperch is classified as a top-predator feeding mainly on perch *Perca fluviatilis* Linnaeus, 1758, smelt *Osmerus eperlanus* (Linnaeus, 1758) and ruffe *Gymnocephalus cernuus* (Linnaeus, 1758) [9]. In its introduced areas, virtually all aspects of the environmental biology of pikeperch require further studies to determine its potential effects in novel environments [5, 10]. Specifically, one of the most urgent needs for basic and applied ecology is to assess the trophic ecology of pikeperch, with reference to other predatory fish species, especially native species.

During the last decade, the study of the trophic ecology and ecological effects of non-native species in freshwaters has greatly benefited from the use of stable isotope analysis (SIA) [1,11]. This method, based on the predictable relationship between the isotopic composition of consumers and their diet, has been proposed as a sensitive, powerful and cost-effective tool [12]. SIA is equally robust at discriminating trophic groups of stream fishes than conventional methods based on gut contents analyses; the difference in the information that can be obtained by both methods relies on the time scale, namely, short (gut contents) *vs.* mid-term

(SIA) [13]. Ratios of carbon isotopes ($\delta^{13}\text{C}$) are used to determine sources of dietary carbon whereas $\delta^{15}\text{N}$ ratios are powerful for estimating trophic position of organisms [14].

The aims of this study were to determine the trophic position of introduced pikeperch within the food web of river ecosystems, and to discuss the potential ecological risks associated with non-native fish introductions. To this end, predatory fish tissues were sampled in two large rivers of SW France, and carbon and nitrogen stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were used to analyze the trophic position differences between co-existing species.

2. Materials and methods

The Lot River flows westward across the Massif Central Mountains for approximately 480 km with a mean discharge of $151 \text{ m}^3 \text{ s}^{-1}$ and a total drainage area of $11,500 \text{ km}^2$. The studied stretch in the Lot River was approximately 4 km long near the town of Puy l'Evêque ($44^\circ 30' \text{N}$, $1^\circ 8' \text{E}$). The Tarn River is about 380 km long with a mean discharge of $144 \text{ m}^3 \text{ s}^{-1}$ and a total drainage area of $15,700 \text{ km}^2$. The studied stretch in the Tarn River, located between two artificial weirs near the town of Villemur-sur-Tarn ($43^\circ 52' \text{N}$, $1^\circ 30' \text{E}$), was approximately 8 km long. Both rivers are tributaries of the Garonne River basin (Fig. 1).

The predatory fish guild in both rivers was mainly composed of one native species (northern pike), and two non-native species (pikeperch and European catfish). Samples of predatory fish were collected from the two rivers by local recreational anglers from mid-April to the end of June 2007. This period corresponded to the most intensive feeding and growth periods of predatory fish [15]. Each individual was measured for total length (TL, $\pm 1 \text{ mm}$) and fin-clipped for SIA. Fin clipping was chosen because stable isotope values in fin tissue correlate closely with those in muscle tissue of fish and thereby allow non-lethal sampling for SIA [16]. All fin samples were oven dried (60°C for 48 h) and ground into a homogeneous powder using a mixer mill (Retsch MM 200). SIA were performed at the Stable Isotopes in Nature Laboratory, University of New Brunswick, Canada.

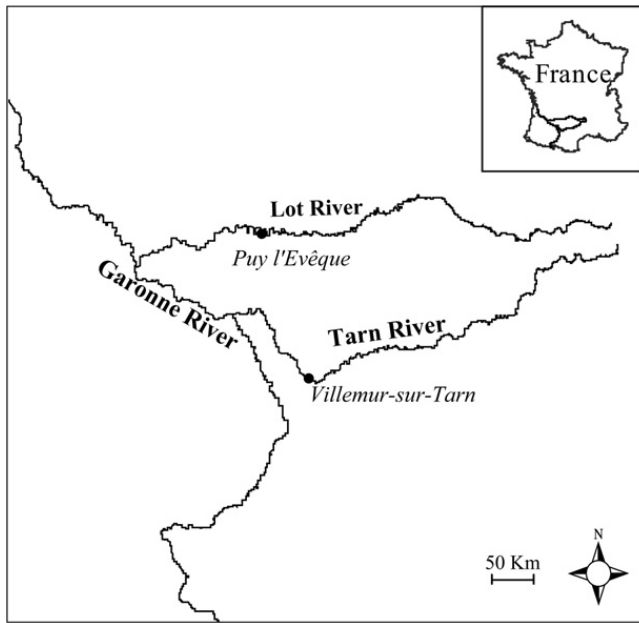


Fig. 1. Location of the sampling areas in the Lot River and in the Tarn River, southwestern France.

Mann–Whitney U -test was used to test for differences between fish total length between the two rivers. After inspection of normality and homoscedasticity, the level of overlapping between the trophic niche of pikeperch, pike and European catfish was determined by comparing the differences in mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values using a one-way ANOVA followed by post-hoc tests (Tukey's multiple comparisons). Since the $\delta^{15}\text{N}$ values cannot directly be used to compare trophic positions of consumers between ecosystems due to potential differences in baseline $\delta^{15}\text{N}$ signatures [17], the $\delta^{15}\text{N}$ signatures of the exotic and invasive Asian clam *Corbicula fluminea* (Müller, 1774) and zebra mussel *Dreissena polymorpha* (Pallas, 1771) were used to correct the $\delta^{15}\text{N}$ values of fish to allow comparisons between the two rivers [14,18]. Mean $\delta^{15}\text{N}$ values of clams were measured from both rivers and the trophic positions (TP) were calculated for each individual using the formula:

$$\text{TP} = [(\text{fish } \delta^{15}\text{N} - \text{clam } \delta^{15}\text{N})/3.4] + 2$$

Table 1

Number (n) of samples analyzed for stable isotopes ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) and total length (TL, minimum, maximum and mean \pm SE, in mm) of pikeperch, pike and European catfish in the Lot and Tarn Rivers.

Species	Lot River				Tarn River			
	n	Total length			n	Total length		
		Min	Max	Mean \pm SE		Min	Max	Mean \pm SE
Pikeperch	15	580	890	676 \pm 26	5	620	750	656 \pm 24
European catfish	14	510	1000	759 \pm 40	10	490	960	626 \pm 42
Pike	6	530	890	627 \pm 20	5	500	770	658 \pm 57

where 3.4 represents a widely used one trophic level fractionation in $\delta^{15}\text{N}$ [14] and 2 is the trophic position of clams.

3. Results

A total of 15 and 5 pikeperch were sampled for SIA in the Lot River and in the Tarn River, respectively (Table 1). The mean (\pm SE) TL of pikeperch was 676 mm (\pm 26, $n = 15$) and 656 mm (\pm 24, $n = 5$), respectively, and did not differ between rivers (Mann–Whitney $U = 130$; $P = 0.921$). A total of 6 and 5 pike were sampled for SIA in the Lot River and in the Tarn River, respectively (Table 1). The mean (\pm SE) TL of pike was 627 mm (\pm 20, $n = 6$) and 658 mm (\pm 57, $n = 5$), respectively, and did not differ between rivers (Mann–Whitney $U = 29$; $P = 0.532$). A total of 24 catfish were sampled in both rivers. The mean (\pm SE) TL of European catfish was 759 mm (\pm 40, $n = 14$) and 626 mm (\pm 42, $n = 5$) in the Lot and Tarn Rivers, respectively, indicating a slight difference between the two rivers (Mann–Whitney $U = 228$; $P = 0.042$).

In the Lot River, the mean $\delta^{13}\text{C}$ value of pikeperch was -23.9‰ (± 0.1) ranging from -24.5 to -22.8‰ , whereas the mean $\delta^{15}\text{N}$ value was 16.7‰ (± 0.2) ranging from 15.48 to 17.8‰ (Fig. 2). In the Tarn River, the stable isotope signatures of pikeperch were -24.5‰ (± 0.1) ranging from -24.9 to -24.1‰ for $\delta^{13}\text{C}$ and 18.5‰ (± 0.3) ranging from 18.0 to 19.2‰ for $\delta^{15}\text{N}$.

In the Lot River, mean $\delta^{13}\text{C}$ values differed significantly between pikeperch and the two other predatory fish (ANOVA, $F_{(2,32)} = 6.096$, $P = 0.006$, Fig. 2), with pikeperch being significantly ^{13}C -depleted compared to pike (Tukey's test, $P = 0.049$) and European catfish (Tukey's test, $P = 0.008$). No significant differences in $\delta^{13}\text{C}$ were found between pikeperch and the two other predatory fish in the Tarn River.

The trophic positions of pikeperch, pike and European catfish differed significantly ($F_{(2,32)} = 46.112$, $P < 0.0001$) in the Lot River (Fig. 3). Specifically,

pikeperch had a higher trophic position than pike (Tukey's test, $P < 0.0001$) and European catfish (Tukey's test, $P < 0.0001$). The same pattern was observed in the Tarn river (Fig. 3) where the three predatory species occupy significantly different trophic positions ($F_{(2,17)} = 27.130$, $P < 0.0001$). Specifically, pikeperch had a higher trophic position than the two other predatory

species (Tukey's test, $P < 0.0001$ for both pike and European catfish). Trophic positions of pike and European catfish were not significantly different neither in the Lot (Tukey's test, $P = 0.083$) nor in the Tarn (Tukey's test, $P = 0.964$).

4. Discussion

Information on the trophic ecology of co-existing native and non-native predators is of importance to virtually all aspects of risk assessment in relation to biological invasions. Particularly, understanding the potential impacts of introduced predators on co-occurring predators and prey can improve our ability to forecast the effects of changes in the composition of the predator guild on the overall community. Basically, such an understanding can be gained by assessing the trophic positions of introduced predators, and potential diet overlap with other species of the predatory guild. Fish species are often studied as model organisms under this topic due to strong fisheries and/or economical concerns [6]. Moreover, many non-native fish species may become rapidly established through human-assisted dispersal (e.g. sport and bait species). Although several studies have described the effects of introduced predatory fish on native prey [19,20], studies focusing on the non-native and native piscivorous fish in rivers are still scarce, but some exists in lakes [1,21]. One of the most successful introduced piscivorous fish, pikeperch, has been widely introduced outside its native area throughout Europe for recreational fishing and commercial value; specifically in areas where its abun-

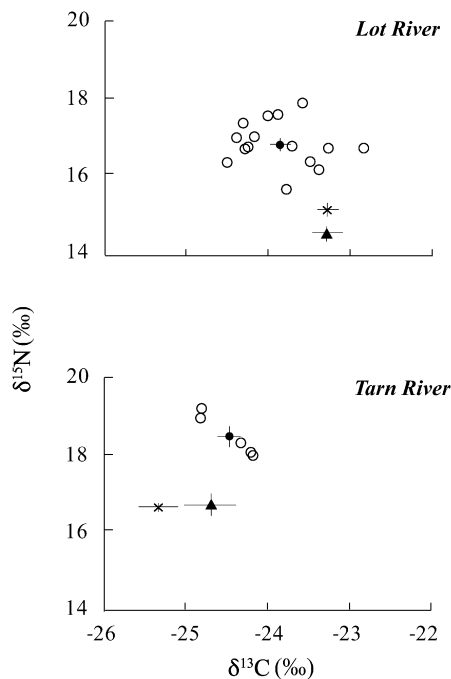


Fig. 2. Mean stable isotope values ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) of pikeperch (●), pike (▲) and European catfish (×) from the Lot (upper panel) and Tarn (lower panel) Rivers. Individual values are given for pikeperch (○). Error-bars represent standard error (SE).

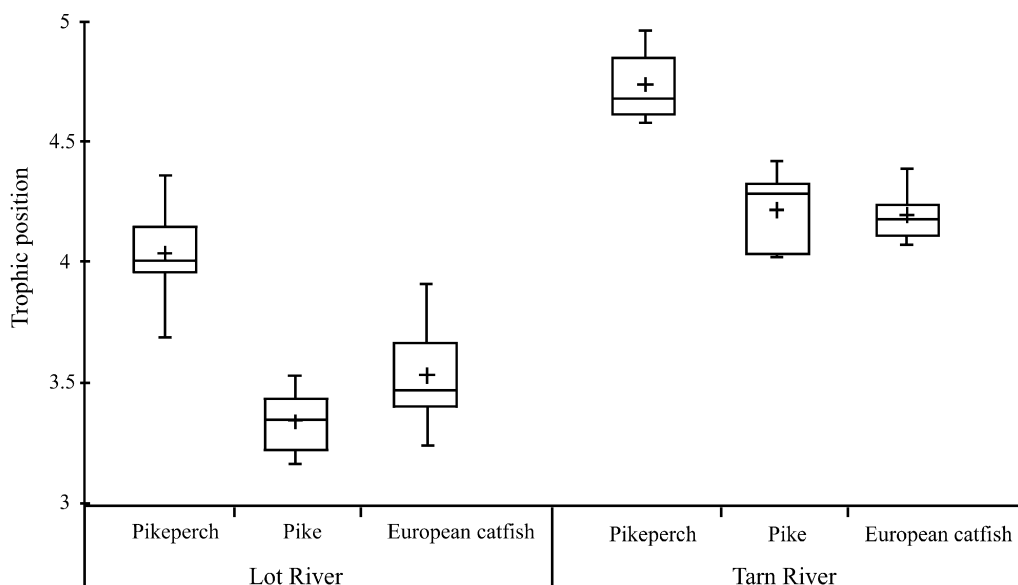


Fig. 3. Trophic position of pikeperch, pike and European catfish in the Lot and Tarn Rivers. The boxes represent the interquartile range, the line across is the median value and the cross is the mean value. The whiskers show the lowest and the highest values.

dance is high enough to support small scale commercial fisheries [22]. This species is also used as a biomanipulation tool to control planktivorous fish abundance in many lake restoration attempts [23].

Here, we assessed the trophic position of the pikeperch within the predatory fish guild in two large rivers using SIA, while other existing studies rather relied on stomach content analyses (but see [24]). SIA is relevant for studying the diet of pikeperch, notably because of the frequency of empty stomachs in predatory fish. Moreover, even if not empty, typically only one or two prey species are found per stomach, and this may lead to highly biased estimates of temporally variable diets [25]. Conversely, SIA integrates diet information over longer time periods [14]. Last, predatory fish are not very abundant in the two studied rivers and they are popular for recreational fishing; hence non-lethal sampling is needed in this context. By the way, we implicitly show that non-specialists (here local anglers) can contribute efficiently to scientific studies on fish diet, by providing researchers with fresh tissue samples. Such a contribution would have probably been complicated, if not impossible, if stomach tubes or pulsed gastric lavage were required for gut contents.

Our results suggest that pikeperch can be categorized as a top-predator in the two studied rivers, but that it occupied a higher trophic position compared to other predatory fish species. Such high trophic levels of pikeperch have been reported in lagoons [24], lakes [19, 26, 27], as well as in marine embayments [28]. However, little was known to date in rivers, although the species is widely introduced in all European rivers [29]. The high trophic position of pikeperch in lakes and reservoirs, assessed from gut content analyses, was often attributed to their feeding preferences on omnivorous fishes like roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*) or smelt as already observed in some French river [25] but also on piscivorous fishes like perch [26, 27] when they reach larger sizes. Furthermore, cannibalism seems to occur throughout the life of pikeperch. Although its importance is modest for individuals smaller than 250 mm [19], cannibalism becomes more important with increasing body size [9, 19, 30] until pikeperch congeners can become the major part of the diet at the adult stage [19] leading to a higher trophic position.

A crucial question about the establishment of non-native species concerns their potential impact on the predator guild. Indeed, most studies concerning resource use frequently treat predatory fish as ecologically equivalent. This simplification would imply that inter-species variation is so weak that it has a limited influence upon interspecific relationships within

the predatory guild, and upon the functional organization of biological communities. Our results indicate that such simplification is not justified and that some predators can be highly specialized compared to other species within the same trophic guild, occupying a higher trophic niche. This study therefore highlights the apparent specialization of a top-predator, which can have important community level implications through intraguild competition and/or predation in the context of species introductions.

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